

# A FIRST DESIGN OF THE PEP-N CALORIMETER

P. PATERI

on behalf of the calorimetry group \*

Laboratori Nazionali di Frascati dell'INFN - via E. Fermi 40, Frascati I-00044

## Abstract

A preliminary design of the PEP-N electromagnetic calorimeter is given. The spatial, energy and time resolutions achievable using a KLOE type electromagnetic calorimeter are presented.

## 1 PHYSICS REQUIREMENTS AND PERFORMANCE GOALS

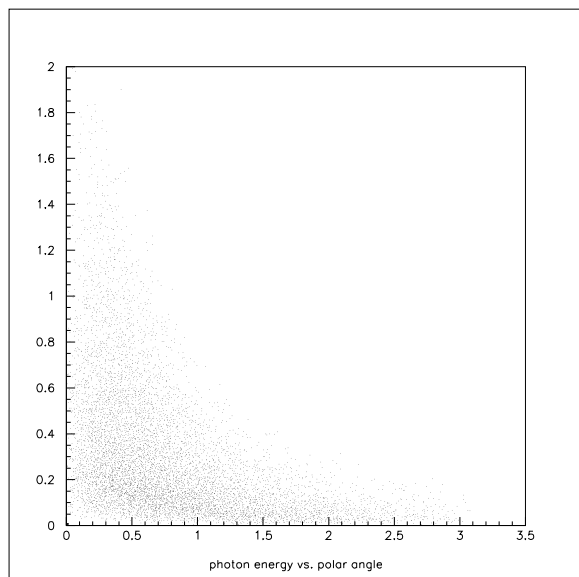


Figure 1: Angular (rad.) energy (GeV) photon correlation for  $e^+e^- \rightarrow 2\pi^+2\pi^-2\pi^0$ .

The main goals of the PEP-N physics programs are :

- a measurement of R with a 2 % or better error. This condition requests the measurement of all exclusive channels.
- a measurement of the  $N\bar{N}$  form factors.
- do spectroscopy in the energy range covered by the machine in order to study new possible final states.

At PEP-N energies, photons with energies lower than 100 MeV are produced, as shown in Fig. 1 for one of the channels with higher cross section  $e^+e^- \rightarrow 2\pi^+2\pi^-2\pi^0$ . In order to achieve these goals the electromagnetic calorimeter should be:

- hermetic.
- have high efficiency, till 20 MeV, for charged and neutral particles.
- have good (few %) energy resolution for photons.
- have good time resolution in order to separate  $N\bar{N}$  events from other final states.

The KLOE electromagnetic calorimeter[1] was designed to detect photons in the (20-500) MeV energy range with good time resolution, so its performances have been taken as guidelines in the design of the PEP-N electromagnetic calorimeter. This detector can provide a fast and unbiased first level trigger, with high acceptance for final states with low energy photons. A good K/ $\pi$  separation is achievable and also some kind of  $\pi/\mu$  discrimination is possible.

### 1.1 The KLOE electromagnetic calorimeter

The KLOE calorimeter is a fine sampling lead and scintillating fibers calorimeter. The barrel modules have trapezoidal cross section, 4.3 m long, 60 cm wide and 23 cm thick. Each module is obtained gluing 0.5 mm thick lead foils worked to house the 1 mm diameter fibers. The resulting structure (Fig. 2) has fiber:lead:glue volume ratio of 42:48:10, an average density of 5 g/cm<sup>3</sup>, a mean radiation length 1.5 cm, and a sampling fraction of  $\sim 15\%$  for minimum ionizing particles. The readout granularity is  $\sim (4.4 \times 4.4)$  cm<sup>2</sup>, for a total number of 4880 read-out channels. A precision in measuring the photon conversion point in the transverse plane of  $\simeq 1$  cm has been achieved. The coordinate along the fiber is measured using the relation:  $z = v_f \cdot \frac{\Delta T}{2}$ , with  $\Delta T$  the time difference at the two module ends and  $v_f$  the effective light propagation speed in the fibers. The measured effective light propagation speed is  $v_f = 17.2$  cm/ns.

The z resolution is  $\sigma_z = \frac{1.24 \text{ cm}}{\sqrt{E(\text{GeV})}}$ . The obtained performances (Fig. 3), are summarized as follows:

- detection efficiency for photons with energy between 20 MeV and 500 MeV of about 99%.

\* co authors : R. Baldini-Ferrolì, M. Cordelli, P. LeviSandri, A. Zallo (INFN Frascati, Italy); V. Bidoli, R. Messi, L. Paoluzzi, E. Santovetti (INFN and University of Rome "Tor Vergata", Italy)

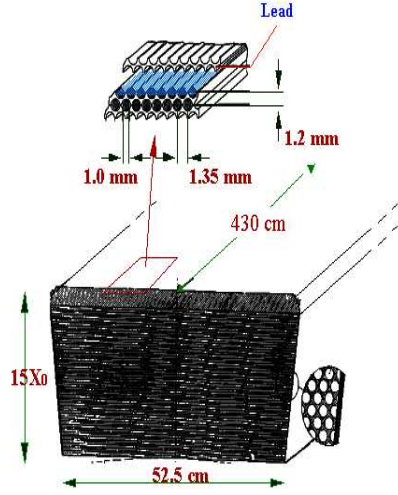


Figure 2: Sketch of a lead-scintillating fiber module.

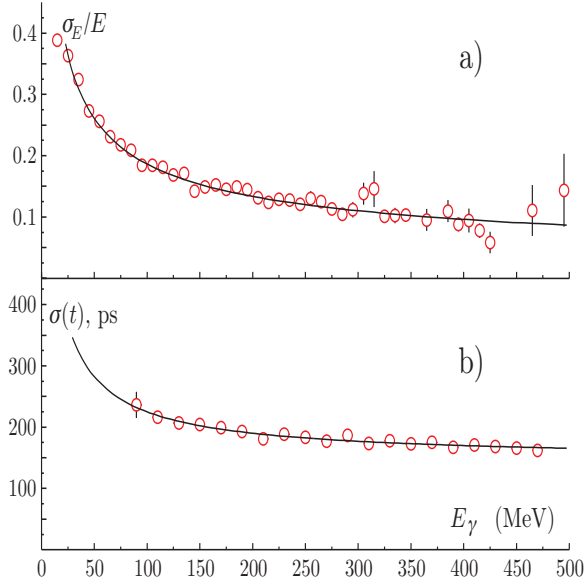


Figure 3: Energy and time resolutions as function of the photon energies.

- resolution in the photon conversion point position in the transverse plane of  $\simeq 1$  cm and in the z coordinate  $\sigma_z = \frac{1.24 \text{ cm}}{\sqrt{E(\text{GeV})}}$ .
- energy resolution  $\frac{\sigma_E}{E} \simeq \frac{5.7\%}{\sqrt{E(\text{GeV})}}$ .
- time resolution  $\sigma_t \simeq \frac{54 \text{ ps}}{\sqrt{E(\text{GeV})}} + 110 \text{ ps}$ .

The calorimeter is inside a 0.6 T magnetic field with a consequent residual magnetic field up to 0.2 T in the photo-

multipliers (PM) area and with an angle with respect to PM axis up to  $25^\circ$ ; for this reason fine mesh photomultipliers, Hamamatsu R5946, were specially designed for KLOE.

## 2 THE PEP-N ELECTROMAGNETIC CALORIMETER

In Fig. 4 an exploded view of the calorimeter design is shown. It consists of barrel, forward and backward detec-

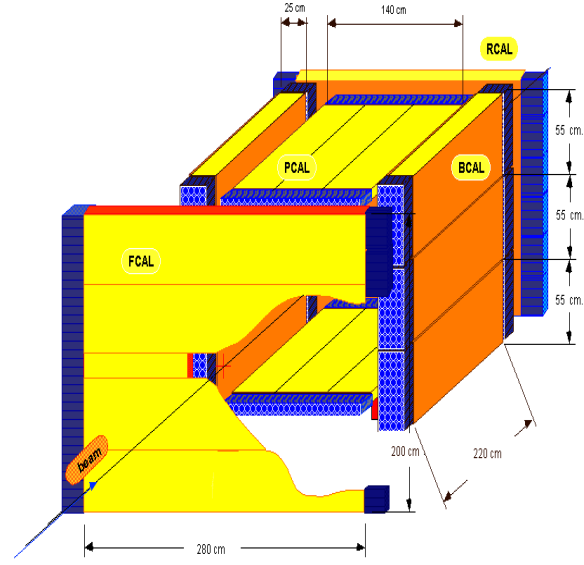


Figure 4: Exploded view of the PEP-N calorimeter.

tors.

- Each of the vertical sides of the *barrel* have 3 modules with rectangular cross section, 220 cm long, 55 cm high and 25 cm thick, with fibers parallel to the beams (BCAL detector). Also the horizontal sides have 3 modules 220 cm long, 50 cm wide, 15 cm thick, positioned over and under the TPC chamber, in order to complete the coverage of the azimuthal acceptance (PCAL detector). The angular region covered by the barrel modules is  $27^\circ < \theta < 135^\circ$ . Due to lack of space PCAL detector is only 15 cm thick. The efficiency and energy resolution, simulated with Monte-carlo, are shown in Fig. 5 and Fig. 6. The efficiency is greater than 99% for energies higher then 40 MeV. The gamma energy resolution is  $\frac{\sigma_E}{E} \simeq \frac{11\%}{\sqrt{E(\text{GeV})}}$  (Fig. 6).
- The *forward detector* (FCAL) is made of modules (Table 1) with the same thickness as BCAL. They are located at  $(130 < z < 155)$  cm, cover an area of  $280 \times 180 \text{ cm}^2$ , with polar angle range  $6^\circ < \theta < 27.5^\circ$  (Fig. 7).
- The *backward detector* (RCAL) is composed of 2 modules positioned at  $z = -140$  cm. They are 120 cm long, 54 cm high and 15 cm thick (Fig. 8), specifically

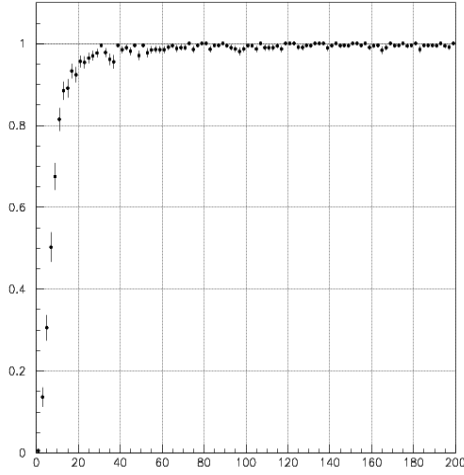


Figure 5: Efficiency for PCAL detector. The  $\gamma$  energies are in MeV.

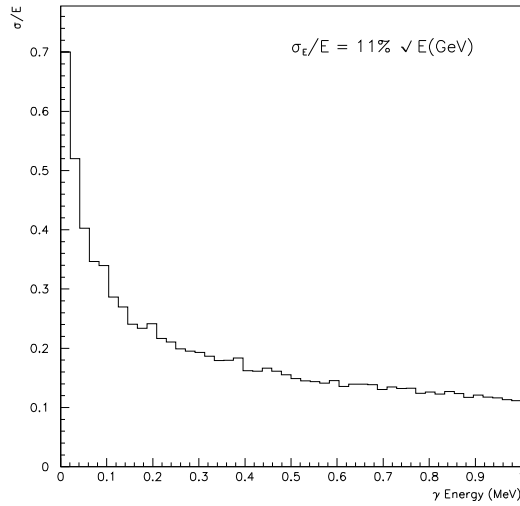


Figure 6: Energy resolution for PCAL detector.

designed to detect very low energy photons. The total area covered is  $120 \times 120 \text{ cm}^2$  ( $135^\circ < \theta < 180^\circ$ ).

In Table 1 the dimensions, number of modules and number of photomultipliers requested are summarized. We have assumed the same readout granularity as KLOE, that is  $\sim (4.4 \times 4.4) \text{ cm}^2$ , so that the total number of photomultipliers is 1350. With this configuration a precision in measuring the photon conversion point in the transverse plane of  $\simeq 1 \text{ cm}$  should be achieved. The inclusive photon energy distributions in the four detectors, at  $E_{\text{cms}} = 2.25 \text{ GeV}$ , is shown in Fig. 9.

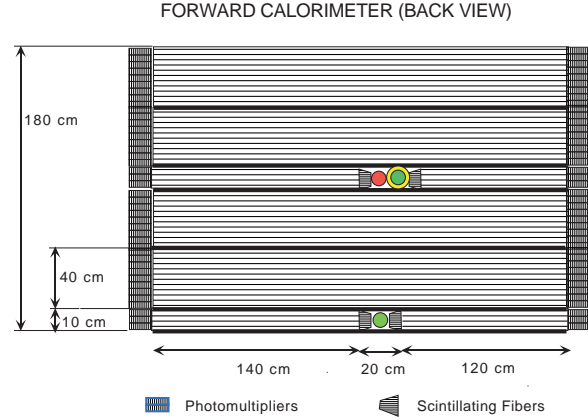


Figure 7: FCAL detector.

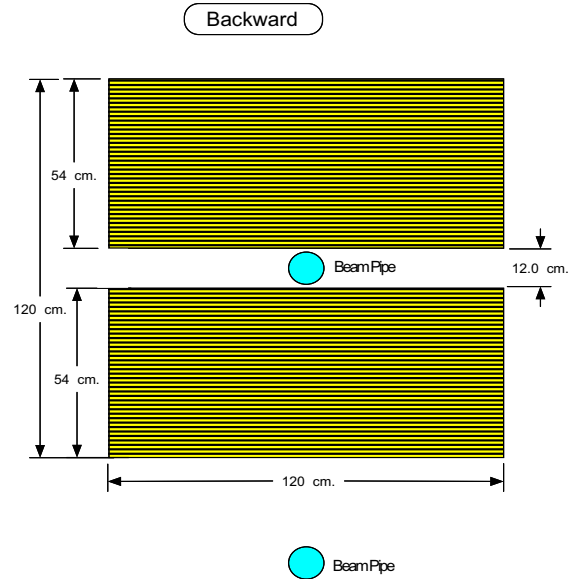


Figure 8: RCAL detector.

### 3 K- $\pi$ SEPARATION USING PEP-N CALORIMETER

The PEP-N detector is equipped with an aerogel detector for K- $\pi$  separation in the  $(0.6 < P_{\text{tot}} < 1.6) \text{ GeV}/c$

Table 1: Sizes(cm), modules and photomultipliers for each detector.

	DX	DY	DZ	Modules	Photom.
PCAL	50	15	220	6	60*6
BCAL	25	55	220	4	110*4
FCAL	280	40	25	4	80*4
	120	10	25	1	20*1
	100	10	25	1	20*1
	140	10	25	2	20*2
RCAL	120	54	10	2	68*2

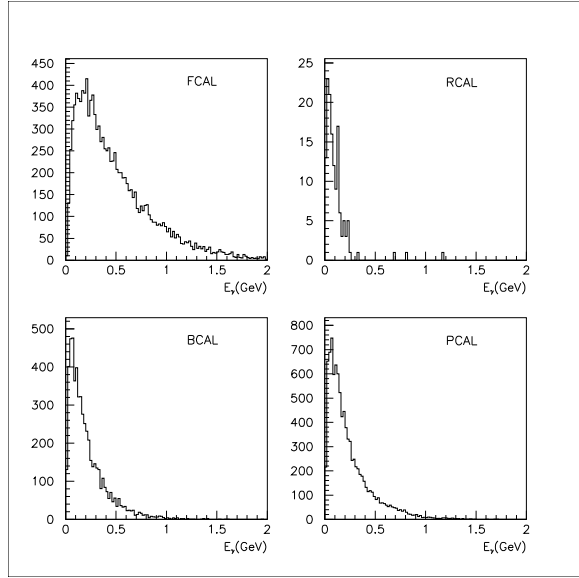


Figure 9: Photon energy distribution in calorimeter detectors.

momentum range. The TPC chamber can be used to separate particles with momenta lower than 0.6 GeV/c (dE/dX measurement). Unfortunately the TPC measures badly the dE/dX of particles hitting the pole calorimeter PCAL where, due to lack of space, it is difficult to insert a specific particle identification detector. Because of very good time resolution, better than 0.2 ns for m.i.p., PCAL can supply these informations. Fig. 10 shows the K- $\pi$  separation as function of the momentum after 1 m of path length. Pions and kaons are well separated till 1 GeV/c momenta after 1 m of path. In Fig. 11 the time-momentum separation for

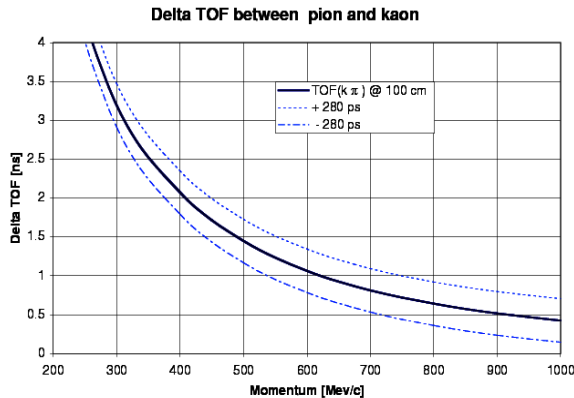


Figure 10: K- $\pi$  separation as function of momentum after 1 m of path length.

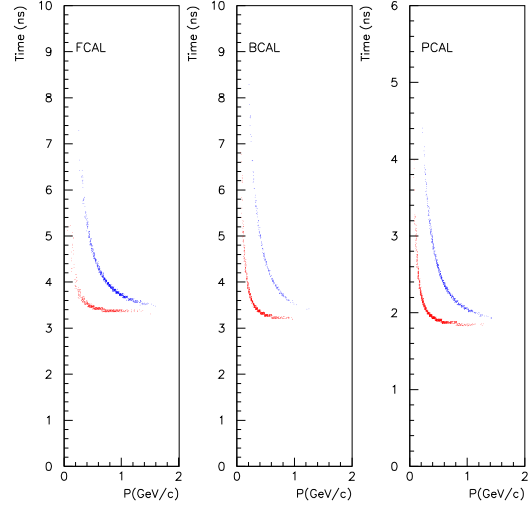


Figure 11: Time(ns) - momentum (GeV/c) correlation for  $KK\pi\pi$  events for FCAL, BCAL and PCAL at  $E_{\text{cms}} = 2.25$  GeV.

the process  $KK\pi\pi$  is shown for FCAL, BCAL and PCAL at  $E_{\text{cms}} = 2.25$  GeV. A  $3\sigma$  separation is shown for these process till 0.8 GeV/c momenta.

## 4 CONCLUSIONS

The present preliminary design of the electromagnetic calorimeter fulfills all the physics requirements for PEP-N. The energy resolution is acceptable, even compared to more expensive crystal detectors. The excellent timing resolution is a very nice feature that could be used to reduce background contributions and do also particle identification. The very high efficiency for very low energy photons gives the possibility to build a minimum bias first level trigger.

## 5 REFERENCES

- [1] M. Adinolfi *et al.*, The KLOE electromagnetic calorimeter, submitted to Nucl. Inst. Meth A.